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(54) STEEL FOR GEAR HAVING EXCELLENT DEDENDUM BENDING FATIGUE CHARACTERISTIC AND FACIAL PRESSURE FATIGUE CHARACTERISTIC AND GEAR

(57)Abstract:

PROBLEM TO BE SOLVED: To provide steel for a gear in which its dedendum bending fatigue strength is higher than that of the conventional gear, further, facial pressure fatigue characteristics are excellent, and mass production is possible and to provide a gear produced by the same steel.

SOLUTION: The gear is composed of the one obtained by forming steel having a composition containing, by mass, 0.10 to 0.35% C, 0.5 to 2.0% Si, 0.2 to 1.0% Mn, 0.01 to 0.50% Ni, 0.5 to 2.5% Cr, 0.01 to 1.00% Mo, 0.005 to 0.200% Al and 0.001 to 0.200% V, and in which the Ac3 temperature parameter is 850 to 940°C, the ideal critical diameter DI is 40 to 400 mm, the carbon equivalent Ceq is ≤1.100, and the temper softening resistance parameter is ≥100 into a gear shape by forging or machine working, in which the content of retained austenite from the surface layer of the gear to the depth position of 100 μm when carburizing treatment or carbo-nitriding treatment is performed is ≤40 vol.%, also, the structure of the core part as a noncarburized part is composed of the dual phase one of ferrite and martensite, and the ratio of ferrite therein is 10 to 45 area

%.

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CLAIMS

[Claim(s)]

[Claim 1] C:0.10 to 0.35, Si:0.5-2.0, Mn:0.2-1.0, nickel:0.01-0.50, Cr:0.5-2.5, Mo:0.01-1.00, aluminum:0.005-0.200, and V:0.001-0.200 (above, mass%) are contained. Further Following the (1) type Ac3=920-203 rootC-15.2nickel+44.7Si+104V-30Mn-11Cr+400aluminum --- (1)

Ac3 temperature parameter computed as be alike is within the limits which is 850-940 degrees C. DI=7.95 rootC (1+0.715Si-0.50Si2) (1+4.1Mn) (1+2.33Cr) (1+0.52nickel) (1+3.14Mo) (1+5V), fB --- (2)

however, fB= -- within the limits whose ideal critical diameter DI computed by 1 (in

Ti<0.005mass% or B<0.0005mass% of the case) or 2 (in Ti>=0.005mass% or B>=0.0005mass% of the case) is 40-400mm -- it is --
Ceq=C+Si/7+Mn/5+V/2+Cr/9+nickel/22+Mo/2 --- (3)
Elements Si and Cr the carbon equivalent Ceq computed as be alike is 1.100 or less, and still more effective in raising resistance to temper softening HSiCr=90Si+23.5Cr --- (4)
Steel for gearings excellent in the deddendum bending fatigue property and planar pressure fatigue property which the resistance-to-temper-softening parameter computed as be alike is 100 or more, and are characterized by the remainder consisting of Fe and an unescapable impurity.
[Claim 2] Furthermore, steel for gearings according to claim 1 characterized by containing Nb:0.010 - 0.100mass% as a chemical entity presentation.
[Claim 3] Furthermore, it is Ti:0.005-0.050 and B:0.0005-0.0100 (above, mass%) as a chemical entity presentation.
Steel for gearings according to claim 1 or 2 characterized by containing.
[Claim 4] It consists of what fabricated the steel for gearings of any one publication among above-mentioned claims 1-3 in the gearing configuration by forging or machining. The amount of retained austenites from a gearing's surface when performing carburization processing or carbonitriding processing to 100-micrometer depth location is below 40 volume %. And the gearing excellent in the deddendum bending fatigue property and planar pressure fatigue property which are characterized by the ratio of the ferrite of them being ten to 45 area % by the organization of the core part which is the non-carburizing section consisting of a two phase organization of a ferrite and martensite.
[Claim 5] Consist of what fabricated the steel for gearings of any one publication among above-mentioned claims 1-3 in the gearing configuration by forging or machining, and carburization processing or carbonitriding processing is performed. The time of performing shot peening beyond arc height 0.3mmA, The amount of retained austenites from a gearing's surface to 100-micrometer depth location is below 40 volume %. And the gearing excellent in the deddendum bending fatigue property and planar pressure fatigue property which are characterized by the ratio of the ferrite of them being ten to 45 area % by the organization of the core part which is the non-carburizing section consisting of a two phase organization of a ferrite and martensite.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the gearing manufactured with the steel for the gearings excellent in the deddendum bending fatigue property and planar pressure fatigue property which are used with the machine part of an automobile and a construction equipment, and others, and this steel.
[0002]
[Description of the Prior Art] The miniaturization of the size accompanying lightweight-izing of the body weight according [the gearing used for the automobile etc.] to recent years and energy saving was required, and buildup of the load of gearing HE by the engine high increase in power has taken place. As for a gearing's endurance, bending fatigue breaking of a deddendum and planar pressure fatigue breaking of a tooth flank mainly become a cause. Among those, in addition to the bending fatigue strength of a deddendum being high, with a gearing with which planar pressure exceeds 2000MPa(s) by Hertzian stress, it is required that the pitching-proof nature of a tooth flank should be especially high.
[0003] Conventionally, the gearing was fabricated using the case hardening steel of JIS SCM420H and SCM822H grade, and surface treatment, such as carburization, has been used, having carried out. However, these gearings were not what can be equal to the activity under high stress. Therefore, the proposal which aimed at improvement in the deddendum bending fatigue strength by modification of steel, modification of the heat treatment approach, and surface work-hardening processing and pitching-proof nature is made.
[0004] For example, raising fatigue strength to it, while reducing the grain boundary oxidizing zone of the front face after carburization heat treatment, and lessening crack initiation, and controlling generation of a slack-quenching layer to JP,7-122118,B and suppressing reduction of surface hardness to it by reducing Si in steel and controlling Mn, Cr, Mo, and nickel, and the technique which controls further the drawing of MnS which promotes crack initiation and propagation by calcium addition are indicated. Hereafter, it is called the advanced technology 1.
[0005] The technique which raises resistance to temper softening to the No. 2945714 patent specification using the steel which added Si 0.25 to 1.50% as a raw material is indicated. Hereafter, it is called the advanced technology 2.
[0006] Distribution of the amount of retained austenites near [which exists after carburization or carbonitriding processing] a surface is specified in JP,7-54050,A, and the technique which raises pitching fatigue strength is indicated. Hereafter, it is called the advanced technology 3.
[0007] A carbonitriding ******** carbonitriding process is performed in JP,7-113145,B using the steel which added Si and Cr which raise resistance to temper softening, and the technique of limiting the sum of the content of C and N near a front face, and controlling the amount of retained austenites is indicated. Hereafter, it is called the advanced technology 4.
[0008] Making resistance to temper softening high and lessening the dispersion and the technique which lessens MnS which lessens S and can serve as an origin of a crack further are indicated by adding V in addition to Si and Cr by JP,8-81743,A. Hereafter, it is called the advanced technology 5.

[0009]
[Problem(s) to be Solved by the Invention] However, the advanced technology mentioned above has the following problem.
[0010] According to the advanced technology 1, by reducing Si, a grain boundary oxidizing zone and a slack-quenching layer can be reduced, and bending fatigue crack generating by the deddendum can be suppressed. However, lowering of resistance to temper softening is invited to reverse, generating of destruction shifts to a tooth flank side from a deddendum, and since it becomes impossible to suppress tempering softening by the frictional heat in a tooth flank and a front face softens, there is a problem of becoming easy to generate pitching.
[0011] On the contrary, according to the advanced technology 2, in order to raise resistance to temper softening, the approach of adding Si etc. and limiting a carburization method of construction to vacuum carburization or plasma carburization for control of grain boundary oxidation progress is adopted, but it is not effective in a manufacturing cost going up by this approach, and fertilizing.
[0012] According to the advanced technology 3, the retained austenite which deposits near the surface metamorphoses into martensite by strain induced transformation, and improvement in bending fatigue strength and pitching-proof nature is in drawing by hardening a gearing front face. However, only now, since softening by the frictional heat of the tooth flank when driving a gearing is not suppressed, it cannot raise pitching-proof nature.
[0013] Like [the advanced technology 4] the advanced technology 3, although the retained austenite of the surface section is controlled, Si and Cr are added to it and coincidence, and drawing of improvement in low ** [softening / tempering] is in them. Thereby, softening by the frictional heat on the front face of a gearing becomes small, and hard facing is expected by the strain induced transformation of retained austenite. However, distortion by transformation arises in that retained austenite becomes martensite by strain induced transformation, and coincidence, and deformation of a tooth flank takes place to them. For this reason, gap arises in gearings' contact surface and it on the contrary becomes easy to generate pitching.
[0014] According to the advanced technology 5, reduction of the dispersion is aimed at with improvement in resistance to temper softening. However, when it is made to drive as a gearing, softening by the frictional heat of a tooth flank is suppressed, but like the advanced technology 4, since gap of the gearing contact surface by the retained austenite near a front face takes place, lowering of pitching-proof nature cannot be suppressed as a result. moreover, although S reduction is considered to be effective so that control of pitching generating by the side of a short time has it, it adds Si, Cr, and V and is hard -- in addition, since machinability, such as gear cutting and oil drilling, is remarkably inferior when S is reduced, the effect in lowering of productivity is larger.
[0015] Therefore, the object of this invention solves the problem mentioned above, and its deddendum bending fatigue strength is higher than the conventional gearing, and it is to offer the gearing manufactured with the steel for [which can be mass-produced] gearings which was excellent in the planar pressure fatigue property further, and this steel.
[0016]
[Means for Solving the Problem] The invention-in-this-application person etc. acquired

the following knowledge, as a result of repeating research wholeheartedly, in order to solve the above-mentioned problem.
[0017] ** Resistance to temper softening is raised by carrying out loading addition of Si of steel, and the Cr, and further, if the dispersion is reduced and softening by generation of heat in the gearing contact surface is suppressed while suppressing Si segregation by addition of V and raising the further resistance to temper softening, surface crack initiation can be controlled.
[0018] ** About the grain boundary oxidizing zone which can serve as an origin of a fatigue crack, by adding Si more than a certain amount, a grain boundary oxidizing zone changes growth in the direction of surface increased density from growth in the depth direction, and the oxidizing zone of it which grew in the depth direction which serves as an origin is lost. Consequently, it is hard coming for the origin of a fatigue crack to come.
[0019] ** the core part organization which the carburization section surface organization of a tooth flank is made into the retained austenite below martensite and 40 volume %, and is the non-carburizing section -- martensite and the ferrite of 10 - 45 area % -- then After driving as a gearing, even if the retained austenite of the surface section serves as a lifting and martensitic structure in strain induced transformation, when the ferrite which is an internal comparatively elasticity organization absorbs distortion, the deformation in the whole becomes small and gap of the gearing contact surface decreases. Consequently, generating of pitching can be suppressed.
[0020] This invention is made based on the knowledge mentioned above, and is characterized by the following.
[0021] Invention according to claim 1 is C:0.10 to 0.35, Si:0.5-2.0, Mn:0.2-1.0, nickel:0.01-0.50, Cr:0.5-2.5, Mo:0.01-1.00, aluminum:0.005-0.200, and V:0.001-0.200 (above). mass% is contained and it is following the (1) type further. Ac3=920-203 rootC-15.2nickel+44.7Si+104V-30Mn-11Cr+400aluminum --- (1)
Ac3 temperature parameter computed as be alike is within the limits which is 850-940 degrees C. DI=7.95 rootC (1+0.715Si-0.50Si2) (1+4.1Mn) (1+2.33Cr) (1+0.52nickel) (1+3.14Mo) (1+5V), fB --- (2)
however, fB= -- within the limits whose ideal critical diameter DI computed by 1 (in Ti<0.005mass% or B<0.0005mass% of the case) or 2 (in Ti>=0.005mass% or B>=0.0005mass% of the case) is 40-400mm -- it is --
Ceq=C+Si/7+Mn/5+V/2+Cr/9+nickel/22+Mo/2 --- (3)
Elements Si and Cr the carbon equivalent Ceq computed as be alike is 1.100 or less, and still more effective in raising resistance to temper softening HSiCr=90Si+23.5Cr --- (4)
The resistance-to-temper-softening parameter computed as be alike is 100 or more, and it has the description for the remainder to consist of Fe and an unescapable impurity.
[0022] Invention according to claim 2 has the description further at a chemical entity presentation according to claim 1 to contain Nb:0.010 - 0.100mass%.
[0023] Invention according to claim 3 has the description further at a chemical entity presentation according to claim 1 or 2 to contain Ti:0.005-0.050 and B:0.0005-0.0100 (above, mass%).
[0024] Invention according to claim 4 the steel for gearings of any one publication among above-mentioned claims 1-3 The time of consisting of what was fabricated in the gearing configuration by forging or machining, and performing carburization processing or carbonitriding processing, The organization of the core part which the amount of retained

austenites from a gearing's surface to 100-micrometer depth location is below 40 volume %, and is the non-carburizing section consists of a two phase organization of a ferrite and martensite, and it has the description for the ratio of the ferrite of them to be ten to 45 area %.

[0025] Invention according to claim 5 consists of what fabricated the steel for gearings of any one publication among above-mentioned claims 1-3 in the gearing configuration by forging or machining, and performs carburization processing or carbonitriding processing. The time of performing shot peening beyond arc height 0.3mmA, The organization of the core part which the amount of retained austenites from a gearing's surface to 100-micrometer depth location is below 40 volume %, and is the non-carburizing section consists of a two phase organization of a ferrite and martensite, and it has the description for the ratio of the ferrite of them to be ten to 45 area %.

[0026] Below, the reason for definition of the numeric value in this invention is explained.

[0027] C: 0.10-0.35mass%C is an element required for reservation on the strength, and although the amount determines the internal hardness after carburization annealing, the amount cannot secure reinforcement as a gearing at 0.10mass(es)%, in order for internal hardness to fall too much. On the other hand, if 0.35mass% is exceeded, toughness lowering and degradation of workability will take place. Therefore, C content was limited to 0.10 - 0.35mass% of within the limits.

[0028] Si: Although 0.5-2.0mass%Si is effective in stopping the grain boundary oxidizing-zone depth while it is an element effective in raising resistance to temper softening, there is no improvement effectiveness of resistance to temper softening that the amount is less than [0.5mass%], and a grain boundary oxidizing zone becomes deep eventually, and deddendum bending fatigue strength is inferior. On the other hand, even if it adds exceeding 2.0mass%, the improvement effectiveness of resistance to temper softening is not only saturated, but toughness deteriorates. Therefore, Si content was limited to 0.5 - 2.0mass% of within the limits.

[0029] Mn: 0.2-1.0mass%Mn is an element which raises hardenability, and, for that purpose, addition beyond 0.2mass% is required for it. However, as an upper limit of addition of hardenability reservation, 1.0mass% is enough. Therefore, Mn content was limited to 0.2 - 1.0mass% of within the limits.

[0030] nickel: Although 0.01-0.50mass%nickel is an element which raises hardenability, more than 0.01mass% is required at least to raise hardenability. However, if the addition exceeds 0.50mass(es)%, a degree of hardness will become high too much, and machinability will deteriorate. Moreover, since nickel is an expensive former funiculus, it requires cost. Therefore, nickel content was limited to 0.01 - 0.50mass% of within the limits.

[0031] Cr: 0.5-2.5mass%Cr is an element which raises resistance to temper softening while being an element which raises hardenability. In order to demonstrate both engine performance, it needs to be added beyond 0.5mass%. However, since the effectiveness which raises resistance to temper softening will be saturated and hardenability will become high too much if the addition exceeds 2.5mass(es)%, toughness deteriorates. Therefore, Cr content was limited to 0.5 - 2.5mass% of within the limits.

[0032] Mo: 0.01-1.00mass%Mo is an element which raises hardenability. For that purpose, even if it adds exceeding 1.00mass%, the effectiveness is saturated, and since

Mo is expensive, profitability is also bad [Mo], although it needs to be added beyond 0.01mass%. Therefore, Mo content was limited to 0.01 - 1.00mass% of within the limits.
[0033] aluminum: 0.005-0.200mass%aluminum is an element effective in deoxidation, and the effectiveness is demonstrated by addition beyond 0.005mass%. Moreover, aluminum combines with N, generates AlN and has the work which suppresses big and rough-ization of crystal grain, and raises toughness, if the effectiveness is effective at addition to 0.200mass% and it is exceeded, a big and rough grain will be generated and toughness will fall. Therefore, aluminum content was limited to 0.005 - 0.200mass% of within the limits.
[0034] V: 0.001-0.200mass%V is an element which raises resistance to temper softening as well as Si and Cr. Moreover, although it also has the effectiveness which forms carbon nitride in it and coincidence, is made to make crystal grain detailed, and controls the segregation of Si, in order to demonstrate the effectiveness, it needs to be added beyond 0.001mass%. However, this effectiveness is saturated even if it adds exceeding 0.200mass%, sufficient effectiveness is not acquired but a manufacturing cost is [a ** top] only **. Therefore, V content was limited to 0.001 - 0.200mass% of within the limits.
[0035] Nb: 0010-0.100mass%Nb is an element which makes crystal grain make it detailed by carbon nitride formation, and, thereby, improvement in deddendum bending fatigue strength is achieved. In order to make crystal grain make it detailed, it needs to be added beyond 0.010mass%. On the other hand, the effectiveness is saturated even if it adds exceeding 0.100. Therefore, Nb content was limited to 0.010 - 0.100mass% of within the limits.
[0036] Although Ti:0.005-0.050mass%B is an element effective in raising hardenability B:0.0005 - 0.0100mass%, the effectiveness is acquired more than at 0.0005mass%, and if 0.0100mass% is exceeded, it will be saturated. Therefore, B content was limited to 0.0005 - 0.0100mass% of within the limits. However, since the improvement effectiveness in hardenability of B is invalid when B exists with N compound, and N is fixed to B addition and this **, it adds Ti. Although the proper addition of Ti changes with amounts of N, 0.005 - 0.050mass% of its within the limits is desirable.
[0037] In addition, in this invention steel, the lower possible one of P as an unescapable impurity and an oxygen content is desirable. Moreover, N is the object which makes crystal grain make it detailed, and addition is allowed to 0.20mass% if needed. Moreover, in order to raise machinability, free-cutting elements, such as S, Pb, Se, and calcium, may be made to contain if needed.
[0038] Ac3 temperature parameter: The heat treatment pattern in the conventional carburization processing is shown in 850-940-degree-C drawing 1 . By the conventional approach, steel is carburized at 930 degrees C, and after making carbon spread and permeate the interior, it hardens at 850 degrees C lower than carburization temperature for distorted reduction. Therefore, at less than 850 degrees C, even if Ac3 temperature parameter computed by following the (1) type holds at 850 degrees C after carburization, it cannot deposit a ferrite in an austenite. Moreover, if it exceeds 940 degrees C, the rate of ferrite area which is an elasticity organization will become large too much, and will serve as lack of on the strength. Therefore, Ac3 temperature parameter computed by following the (1) type should be limited within the limits of 850-940 degrees C.
[0039]

Ac3=920-203 rootC-15.2nickel+44.7Si+104V-30Mn-11Cr+400aluminum --- (1)
(Ideal-critical-diameter DI): 40 - 400mm ideal critical diameter (DI) is a value which shows the hardenability of steel. In less than 40mm, since the hardness of the capital in a gearing becomes low too much, the ideal critical diameter (DI) computed by following the (2) formula cannot secure bending fatigue strength of a desired deddendum. On the other hand, if it exceeds 400mm, the toughness inside a gearing will deteriorate. therefore, the ideal critical diameter (DI) ******(ed) following the (2) type 4 should be limited within the limits of 40-400mm.
[0040]
DI=7.95 rootC (1+0.715Si-0.50Si2) (1+4.1Mn) (1+2.33Cr) (1+0.52nickel) (1+3.14Mo) (1+5V), fB --- (2)
however, fB= -- 1 (in Ti<0.005mass% or B<0.0005mass% of the case), or 2 (in Ti>=0.005mass% or B>=0.0005mass% of the case)
Carbon equivalent (Ceq) <=1.100 carbon equivalent (Ceq) is an index important for determining internal strong ** of front [carburization] hardness and a gearing. When the carbon equivalent (Ceq) computed by following the (3) formula exceeds 1.100, since the hardness before carburization becomes high too much, cutting becomes difficult, and productivity will be dropped. Therefore, the carbon equivalent computed by following the (3) formula should be limited to 1.100 or less.
[0041]
Ceq=C+Si/7+Mn/5+V/2+Cr/9+Ni/22+Mo/2 ---(3)
A tempering softening **** parameter (HSiCr) >=100 resistance-to-temper-softening parameter is a value which shows extent of softening after annealing of steel. Softening in the contact surface when the resistance-to-temper-softening parameter (HSiCr) computed by following the (4) type drives under high planar pressure less than by 100 becomes large too much, it becomes easy to generate pitching, and planar pressure fatigue strength deteriorates. Therefore, the resistance-to-temper-softening parameter (HSiCr) computed by following the (4) type should be limited to 100 or more.
[0042]
HSiCr=90Si+23.5Cr ---(4)
When it exists in the surface of a tooth flank, the amount of retained austenites <=40 volume % retained austenite of a tooth flank surface metamorphoses into martensite with the stress under actuation of a gearing, and although it is elasticity in itself, since it hardens, it has the effectiveness which controls crack progress to bending and planar pressure fatigue. However, if retained austenite exceeds 40 volume %, lowering of surface hardness will become large too much at reverse, and a planar pressure fatigue property will worsen. Therefore, the amount of retained austenites should be limited to below 40 volume %.
[0043] When the gearing which performed ferrite area %:10 - 45% carburization hardening and annealing of the interior (non-carburizing section) organization of a gear tooth is made to drive, the retained austenite which existed in the carburization section changes with strain induced transformation to martensitic structure. At this time, distortion arises by cubical expansion, gap takes place to gearings' contact surface, and planar pressure fatigue strength falls. Therefore, in order to acquire that effectiveness, the ferrite at least is required [the distorted absorption by the ferrite which is an elasticity organization is effective, and], in order to lessen this distortion and to lose lowering of

planar pressure fatigue strength 10% or more during an organization. However, since the hardness of the non-carburizing section falls when 45% or more of ferrites exists, it becomes insufficient [reinforcement] and endurance deteriorates. Therefore, the rate of ferrite area of the non-carburizing section should be limited to 10 - 45% of within the limits.

[0044] Arc height of shot peening (S/P): If 0.3 or more mmAs shot peening is performed, compressive residual stress can be given near a surface and bending fatigue strength and planar pressure fatigue strength can be raised further. When performing this processing, since arc height has too little grant of compressive residual stress, it cannot cover further the expenses [mmAs / less than 0.3] of bending fatigue strength and planar pressure fatigue strength. Therefore, as for shot peening, it is desirable to give more than by arc height 0.3mmA.

[0045] In addition, arc height is SAE (specification of American Society of Automotive Engineers). It is an index showing the strength of shot peening by J442a. After fixing a 19mmx77mm tabular test piece and projecting a shot throughout one side of this test piece, if a test piece is removed, curvature (deflection) will have occurred in the test piece. This amount of curvatures (deflection) is called arc height. In addition, A is the class of thickness of a test piece and means 1.3mm.

[0046]

[Embodiment of the Invention] An example explains this invention to a detail further.

[0047] The steel of No.1-15 which have the chemical entity presentation shown in a table 1 was dissolved, respectively, and the ingot was prepared. No.1-7 [in addition,] shown in a table 1 -- this invention steel and No.8-13 -- comparison steel and No. -- 14 and 15 are steel conventionally. For steel, No.14 are JIS conventionally. SCM420H and No.15 are SCM822H. The value of Ac3 temperature parameter of each steel, an ideal critical diameter DI, a carbon equivalent Ceq, and the resistance-to-temper-softening parameter HSiCr is doubled, and it is shown in a table 1.

[0048]

[A table 1]

鋼番	No.	化学成分(wt%)												Ceq	Ac3 (℃)	DI (mm)	Hsio
		C	Si	Mn	Ni	Cr	Mo	V	Nb	SolAl	Ti	B	N				
本発明鋼	1	0.34	1.24	0.98	0.20	0.54	0.03	0.155		0.098			0.0099	0.875	865	125	124
	2	0.12	1.97	0.21	0.05	2.11	0.33	0.132		0.032			0.0121	0.911	934	48	227
	3	0.22	0.54	0.52	0.12	2.46	0.15	0.189		0.193			0.0095	0.849	896	296	106
	4	0.15	1.33	0.33	0.48	1.54	0.97	0.003		0.005			0.0103	1.085	890	181	156
	5	0.23	1.70	0.40	0.07	1.50	0.40	0.150	0.020	0.031			0.0090	0.998	900	141	188
	6	0.22	1.60	0.43	0.10	1.33	0.32	0.102		0.025	0.024	0.0033	0.0078	0.898	888	115	175
	7	0.20	1.55	0.63	0.11	1.03	0.22	0.197	0.024	0.036	0.035	0.0022	0.0075	0.875	898	138	164
比較鋼	8	0.09	2.05	0.34	0.08	1.55	0.77	0.132		0.032			0.0121	1.078	963	54	221
	9	0.36	1.03	1.06	0.09	1.30	0.33	0.205		0.035			0.0099	1.135	832	533	123
	10	0.24	0.84	0.67	0.10	2.57	0.72	0.002		0.003			0.0087	1.145	822	440	136
	11	0.22	0.44	0.54	0.04	2.43	0.35	0.154		0.114			0.0109	0.915	864	369	97
	12	0.21	0.98	0.66	0.11	0.47	0.25	0.110		0.087			0.0106	0.719	888	101	99
	13	0.22	1.53	0.18	0.12	0.83	0.12	0.065		0.029			0.0088	0.665	889	34	157
従来鋼	14	0.23	0.23	0.78	0.07	1.13	0.18			0.035			0.0100	0.638	808	107	47
	15	0.22	0.25	0.76	0.08	1.11	0.38			0.025			0.0103	0.725	812	144	49

[0049] thus, this invention test-piece No.1-7 which hot-roll each ingot of steel the prepared above-mentioned this invention steel, comparison steel, and conventionally, and consist of a diameter of 32mm, and 70mm round bar steel, comparison test-piece No.8-13, and the former -- test-piece No. -- 14 and 15 were prepared. Subsequently,

normalizing processing was carried out to each test piece obtained by doing in this way, the following trial was presented with each test piece after normalizing processing, and it was investigated about the austenite grain size of a hardening deformation amount, surface retained austenite, the rate of ferrite area of the non-carburizing section, a rotary bending property, a planar pressure fatigue property, internal hardness, internal toughness, a grain boundary oxidizing zone, and the carburization section. This result is shown in a table 2.

[0050]

[A table 2]

鋼番	No.	粒界酸化層 (μm)		内部衝撃値 J/cm²	内部硬さ HV	浸炭部γ粒度	残留γ量 (%)		フェライト面積率 (%)	焼入れ歪量 (%)	回転曲げ疲労強度 (MPa)		面圧疲労強度 (MPa)	
		浸炭材	S/P材				浸炭材	S/P材			浸炭材	S/P材	浸炭材	S/P材
本発明供試体	1	3.00	<1	99	364	9.5	26	23	10.3	0.77	858	1009	2839	2989
	2	3.00	<1	98	411	9.5	29	25	44.8	0.50	899	1058	2932	3087
	3	4.00	<1	93	357	9.7	31	27	13.8	0.89	824	970	2792	2940
	4	5.00	1	99	419	8.9	37	32	40.3	0.78	916	1078	2978	3138
	5	3.00	<1	96	396	9.7	36	31	24.6	0.73	891	1049	2932	3087
	6	4.00	<1	99	370	9.5	30	26	24.8	0.55	866	1019	2885	3038
	7	4.00	1	93	364	9.8	36	31	23.0	0.53	849	1000	2932	3087
比較供試体	8	3.00	<1	46	288	9.6	22	19	48.0	0.56	691	813	2699	2842
	9	3.00	<1	33	432	9.5	50	43	8.8	2.35	699	823	2141	2254
	10	5.00	1	44	422	6.4	32	28	6.4	2.64	683	804	2141	2254
	11	18.00	5	94	375	9.3	30	26	16.2	1.56	695	818	2373	2499
	12	3.00	1	99	296	9.4	35	30	20.4	1.63	695	818	2234	2352
	13	3.00	<1	95	309	9.5	33	29	27.8	0.55	691	813	2745	2891
従来供試体	14	16.00	5	101	299	8.8	36	31		3.11	691	813	2187	2303
	15	15.00	4	99	325	8.6	38	33		3.33	708	833	2327	2450

[0051] ** The navy C test piece was processed from each test piece with a diameter of 70mm by which hardening deformation amount normalizing was carried out. The front view of a navy C test piece is shown in drawing 2 , and the side elevation is shown in drawing 3 R> 3. The navy C test piece 1 has opening 2 and the disc-like space 3 on a disc-like object, as shown in both drawings, and the dimension of each part of a test piece is as follows.
[0052] The trial of the hardening deformation amount measurement by (distance

p):10.2mm carburization hardening and annealing with the (diameter c):34.8mm opening (spacing d):6mm test piece core of Test piece (Diameter a):60mm thickness (b):12mm disc-like space, and an opening circle core After producing the above-mentioned navy C test piece 1 each ten sample offering bodily crushes and carrying out carburization hardening and annealing for these test pieces, the rate of change before and behind carburization hardening / annealing of opening spacing (d) of a test piece was measured, and this value was defined as the hardening deformation amount. When the deformation after carburization hardening / annealing by the navy C test piece produces a carburization gearing using the steel in which a big value which exceeds 2.0% is shown and the retained austenite which exists near a gearing's tooth flank surface carries out a martensitic transformation with shot peening and the stress after making it work as a gearing, deformation of a tooth flank becomes large too much, and a planar pressure fatigue property gets worse. Therefore, 2.0% or less of a hardening deformation amount is desirable.

[0053] Furthermore, even if it lessens both deformation by the transformation to martensitic structure from the austenite texture by carburization hardening and annealing, and deformation of the tooth flank by the transformation to martensitic structure from the retained austenite organization in a gear drive and does not carry out a gearing's tooth-form correction grinding after carburization hardening / annealing, in order to obtain a gearing with a good planar pressure fatigue property, it is desirable for the deformation amount by this trial to be 1.0% or less. The test result of a hardening deformation amount is the average of the trial number of cycles n= 10.

[0054] ** Using the test piece [finishing / surface retained austenite % carburization hardening deformation amount measurement], two of ten test pieces of each test piece were extracted, and shot peening of arc height 0.6mmA was performed to one of test piece transverse-plane parts of it. And about each one shot-peening implementation test piece [of each test piece], and shot-peening non-carried out test piece 1 piece, the amount of retained austenites was measured for every 20-micrometer depth from the surface of a transverse-plane part to the depth location of 100 micrometers, and the average was calculated. In addition, electrolytic polishing was used for polish of a measuring plane, and X-ray diffractometer was used for measurement.

[0055] ** One of a test piece [finishing / the ferrite area % carburization hardening deformation amount of the non-carburizing section and the amount measurement of surface retained austenites] was cut, the ratio into which it observes ten visual fields of each test piece at a time, and a ferrite occupies the ferrite-martensitic structure of the interior (non-carburizing section) in carburization hardening and annealing of each test piece in each visual field by speculum trial was measured with the image processing system, the average of the ten visual fields was calculated, and it was defined as ferrite area %.

[0056] ** From each test piece with a rotary bending fatigue property diameter of 32mm, the test piece with a parallel part diameter of 10mm was extracted, and the rotary bending fatigue test specimen which covered the perimeter and attached the notch (fatigue notch factor: 1.4) with a depth [of this and the direction of a right angle] of 3mm to the parallel part was prepared. Carburization hardening / tempering processing was performed on the conditions given to the navy C test piece to this test piece total. Then, shot-peening processing (arc height: 0.6mmA) was performed to the half test piece. And

about a shot-peening implementation article and non-carried out elegance, the rotary bending fatigue test was performed by having made 107 times into the fatigue limit using an Ono style rotary bending fatigue tester, and rotary bending fatigue strength was measured.

[0057] ** Pitching trial (planar pressure fatigue property)

The pitching test piece 4 which is shown in drawing 4 from each test piece with a diameter of 32mm and which has the body whose width of face the diameter of a trial side is 26mm and is 28mm was produced. Furthermore, as shown in drawing 5 , after considering as the diameter of 135mm with forging using each test piece with a diameter of 70mm, normalizing processing was performed and the large roller 5 with a diameter [of 130mm] and a width of face of 18mm was produced. Subsequently, carburization hardening / tempering processing was performed to the letter test piece 4 of pitching, and the large roller 5 on the same conditions as a navy C test piece and a rotary bending fatigue test specimen. Then, shot-peening processing (arc height: 0.6mmA) was carried out on the conditions same about each moiety as a rotary bending fatigue test specimen. And it examined by making 107 times into a fatigue limit about a shot-peening implementation article and non-carried out elegance using the roller pitching testing machine. The test condition at that time was as follows.

[0058] number of revolutions: -- 1500rpm slip ratio: -- 40% lubricant: -- mission oil oil-temperature: -- in the vertical section, Vickers hardness was measured in a certain predetermined pitch from the surface part about the test piece with 120 degree-C** carburization effective case depth hardended by carburizing treatment, the austenite grain size of the carburization section, a grain boundary oxidizing zone, an internal hardness, and a diameter [after internal toughness carburization hardening / annealing] of 32mm, and the depth from which hardness serves as 550Hv(s) was made into carburization effective case depth hardended by carburizing treatment. Subsequently, the Vickers hardness number of the interior which is the non-carburizing section was measured, and the value estimated the reinforcement of a gearing core part. Moreover, from the non-carburizing section, the JIS No. 3 impact test specimen was prepared, the impact test was performed, and the result estimated the toughness of a gearing core part. Moreover, shot peening was selectively performed about the same test piece, and the grain boundary oxidizing zone of the surface in a vertical section was investigated by speculum observation about one cross section each of shot-peening a non-carried out part, and an operation part. Moreover, it investigated also about the austenite grain size of the carburization section.

[0059] Although No.1-7 which are this invention steel reach steel No.14 conventionally and internal toughness, the carburization section grain size number, and the amount of retained austenites are equivalent compared with 15 so that clearly from a table 1 and a table 2, internal hardness is high and the grain boundary oxidizing zone is small. Therefore, rotary bending fatigue strength is improving. Moreover, since a resistance-to-temper-softening parameter (HSiCr) is high and there is little heat deformation by the ferrite of the non-carburizing section, planar pressure fatigue strength is rising remarkably.

[0060] On the other hand, comparison steel No.8 have C content lower than this invention range, and its Si content is high across this invention range. Therefore, a ferrite deposits more than this invention range, and since internal hardness is low, rotary

bending fatigue strength is falling to the interior.
[0061] C content, Mn content, and V content have exceeded this invention range, and a carbon equivalent (Ceq) and the ideal critical diameter (DI) of comparison steel No.9 are higher than this invention range. Therefore, internal toughness is falling, therefore rotary bending fatigue strength is falling. Moreover, three Ac(s) temperature parameter becomes lower than this invention range, and the rate of ferrite area is smaller than this invention range. Therefore, since the hardening deformation amount increased, planar pressure fatigue strength is falling.
[0062] Since as for comparison steel No.10 Cr content was high across this invention range, the carbon equivalent (Ceq) and the ideal critical diameter (DI) had it and the internal impact resistance value became low, rotary bending fatigue strength is falling. [higher than this invention range] Moreover, since aluminum content is lower than this invention range, crystal grain also becomes large, and since three Ac(s) temperature parameter was lower than this invention range and the rate of ferrite area became lower than this invention range, a hardening deformation amount becomes large, therefore planar pressure fatigue strength is falling.
[0063] Comparison steel No.11 had few Si contents than this invention range, therefore the grain boundary oxidizing zone became large. Moreover, a resistance-to-temper-softening parameter (HSiCr) is also lower than this invention range. Therefore, rotary bending fatigue strength and planar pressure fatigue strength are falling.
[0064] Since comparison steel No.12 have few Cr contents than this invention range, its a softening resistance parameter (HSiCr) is also lower than this invention range. Therefore, planar pressure fatigue strength is falling.
[0065] Since comparison steel No.13 had few Mn contents than this invention range, the ideal critical diameter (DI) became lower than this invention range. Therefore, since internal hardness fell, rotary bending fatigue strength is also falling.
[0066] It reaches steel No.14 conventionally and 15 is JIS. Although it is SCM420H and SCM822H, Si content is lower than this invention range, and three Ac(s) temperature parameter is lower than this invention range, and the resistance-to-temper-softening parameter HSiCr is less than this invention range. Consequently, internal hardness is lower, crystal grain is larger than this invention steel, and a ferrite does not exist in the non-carburizing section. Moreover, a grain boundary oxidizing zone is large. Therefore, rotary bending fatigue strength and planar pressure fatigue strength are falling.
[0067]
[Effect of the Invention] Without changing the conventional production process to the conventional gearing used for an automobile, an industrial machine, etc. according to this invention, as explained above, it has a bending fatigue property more than before, and the useful effectiveness that the gearing which needs the high planar pressure of 2000 or more MPas can be mass-produced further is brought about.

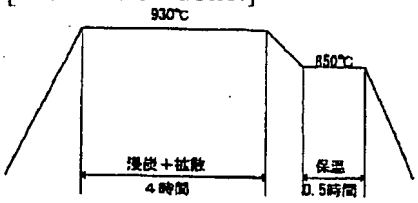
[Translation done.]
* NOTICES *

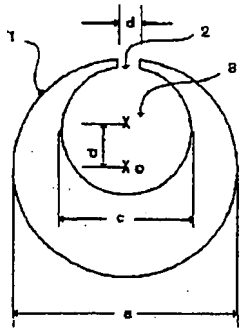
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

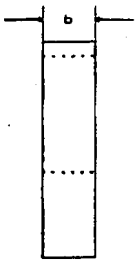
DESCRIPTION OF DRAWINGS

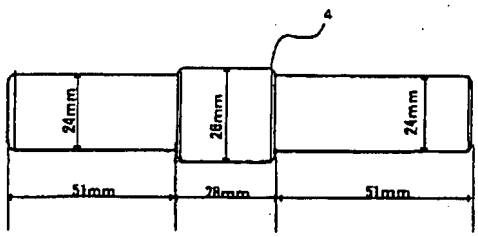
[Brief Description of the Drawings]
[Drawing 1] It is drawing showing a carburization processing pattern.
[Drawing 2] It is the front view showing a navy test piece.
[Drawing 3] It is the side elevation showing a navy test piece.
[Drawing 4] It is the front view showing a pitching test piece.
[Drawing 5] It is the perspective view showing the device of a pitching trial.
[Description of Notations]
1: Navy test piece
2: Opening
3: Space
4: Pitching test piece
5: Large roller

[Translation done.]





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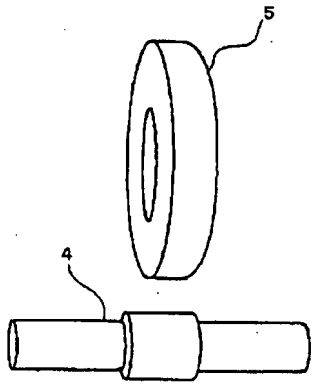
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